ROTOR BLADE FOR A WIND-DRIVEN POWER-PLANT.

The present invention relates to a rotor blade for a power-plant fitted with a device optimizing aerodynamics as defined in the preamble of claim 1.

Wind-driven power-plants comprise a rotor fitted with one or more rotor blades. Each rotor blade in turn comprises a sectional blade contour, which is perpendicular to the blade's direction from blade root to blade tip, and of which the thickness decreases toward the outside, from the blade root toward the blade tip. Said blade contour entails a suction side and a pressure side, so that when air is moving around the blade, the suction side is at a lower pressure than the pressure side. The pressure differential across the pressure and suction sides generates lift causing the rotor rotation which in turn is used to drive an electric power generator.

High rotor efficiency and hence high wind-driven power-plant output assumes as smooth as possible an airflow around the blade contour perpendicularly to the axis of the rotor blade and over the entire range of the rotor blades.

However it is noted with respect to known rotor blades that the airflow moving around the blade contour will detach at the suction side and that a wake zone is generated which, by increasing drag, reduces the rotor blade lift and decelerates the rotor blade. Typically the term "wake zone" denotes the region of the detached airflow. Both factors lower the wind-driven power-plant productivity.

Seen in the direction of flow, airflow detachment as a rule takes place beyond the highest relative depth of the blade contour. In general at least the zones near the blade root will be affected.

Vortex generators are a known means to reduce airflow detachment ands thus to optimize aerodynamic airflow around the blade contour. Such generators as a rule are in the form of sheetmetal, bars or cross-sectionally shaped structures and the like configured at the suction side of the rotor blade and generating local turbulences reducing large-area detachment of the airflow around the blade contour. Illustratively such vortex generators are known form the patent document WO 0015961. These known vortex generators incur the draw-

back that they only slightly improve wind-driven power-plant productivity because they themselves generate drag and furthermore are very noisy.

The objective of the present invention is to create a wind-driven power-plant rotor blade that offers substantially improved aerodynamic airflow around the blade. This problem is solved by the features of claim 1.

The solution to this problem is comprehensively discussed below and is based on the insight that interfering flows are generated in particular in the zone of the rotor root at the suction side of the blade contour and run transversely to the rotor blade toward the blade tip. These cross-flows arise substantially in the region of the detached airflow and are assumed due to the pressure differentials caused by different incident airflow speeds at different blade radii; they are induced in especially marked manner in the blade root zone. In addition to these factors, the centrifugal forces acting on the rotor blade also contribute to generating said cross-flows.

The detachment in the rotor-blade root zone is moved by said cross-flow out of the airflow around the aerodynamically disadvantageous blade root zone toward the blade tip, that is into the zone of the aerodynamically more advantageous blade contours. Moreover the cross-flow also interferes with the effective airflow around the rotor blade because generating turbulences that entail premature airflow detachment.

Accordingly the present invention provides a wind-driven power-plant rotor blade fitted with a device optimizing the airflow around the blade contour, said device comprising at least one planar element mounted by one of its thin sides on the suction side and substantially pointing in the direction of airflow, said element being configured in the zone the above cited cross-flow running outward on the suction side of the contour from the blade root, the height and length of the device being selected that it shall substantially reduce said cross-flow.

The reduction of the cross-flow by said planar element prevents premature airflow detachment from the rotor blade suction side. Such improved blade-enveloping airflow

achieves a considerable increase in the output of a correspondingly equipped wind-driven power-plant without entailing an increase in operational noise.

The required height and length of the particular planar element and the optimal position of this element on the suction side of the rotor blade inherently varies with the distance from the rotor axis of rotation, the blade contour depth, the rotor width, the most likely speed of the incident airflow, etc.

In the simplest way, the best configuration is ascertained empirically, for instance by affixing rows of wool threads at one end to the rotor blade and by field tests visually determining the prevailing airflow conditions by means of the said threads' free ends. In this manner the effect of planar elements of the invention on the airflow conditions may be ascertained relatively easily in various radius positions and consequently also the optimal number and positions, if called for also the sizes, of the planar elements of the invention.

The wool threads may be configured, if called for additionally, on differently sized spacers, in the form of bars for instance, to determine the wake zone depth caused by the cross-flow and hence the height of the cross-flow to be stopped.

This procedure allows empirically ascertaining the optimal height and length of the planar elements of the invention and/or their optimal positions on a particular rotor blade. Running corresponding series of tests, the optimal dimensions and positions of the planar elements of the invention may be determined for arbitrary types of rotor blades.

Planar elements preventing cross-flows mounted on the suction side of an airfoil have long been known in aeronautical engineering. These elements are especially widely used in swept-back wing aircraft. In this design, the problem arises that on account of the obliqueness of the leading airfoil edge, a pressure gradient is generated which deflects the air flowing around the airfoil toward the airfoil tip. This undetached cross-flow in turn interferes with the airflow around the airfoil and hence reduces the lift because the airflow moves along the wing, but no longer on it. To reduce the cross-flow, therefore, perpendicular barriers are affixed to such airfoils and are denoted as boundary layer fences.

These boundary layer fences differ as regards their essential features from the above-cited planar elements of the invention for wind-driven power-plant rotor blades. The undetached cross-flows at sweptback airfoils being induced foremost in the region of the airfoil leading edge, this is precisely the area where the boundary layer fences are erected. Frequently said fences even run around the airfoil leading edge as far as to said airfoil pressure side.

The wind-driven power-plant's rotor blade planar elements of the invention on the other hand reduce a cross-flow which was caused by other phenomena and which already has detached and which arises predominantly in the region of maximum depth of rotor blade contour and induces airflow detachment in the region of said maximum depth. Configuring such elements merely in the region of the rotor blade leading edge would be inappropriate.

In one preferred embodiment of the present invention, the planar element is configured at least in the zone of the cross-flow running on the blade contour suction side between a zone of maximum relative blade depth and blade trailing edge. This cross-flow is the above described flow that was generated by the speed differential of the incident airflow between the zones near the rotor blade root and the zones near the blade tips and by the resulting pressure gradients at the rotor blade suction side and also the centrifugal forces at the rotor blade.

In an especially preferred embodiment mode of the present invention, the planar elements extend over the full width of the rotor blade suction side. In this manner encroaching by the cross-flow into zones of proper airflows is precluded even without knowledge of the accurate path of the cross-flow on the rotor blade suction side.

In a further preferred embodiment of the invention, the planar element is designed so that its length runs straight. In this manner the planar element's drag is kept small and noise is minimized. In an especially preferred embodiment mode, the planar element runs no more than 10° away from the tangent to that circle formed by the rotor blade radius which is subtended by the planar element position.

In a further preferred embodiment of the invention, the planar element is designed so that its longitudinal direction follows the radius path corresponding to the distance between the planar element's front end and the rotor's axis of rotation. In turn this design makes it possible to minimize said element's drag and its noise.

In a further preferred embodiment of the invention, the rotor blade is fitted at the suction side of its contour with several planar elements. This design is appropriate when, behind the first element, a new cross-flow as discussed herein shall be produced. Optimal positioning and sizing of these several planar elements on the rotor blade can be implemented as described above,

In a further preferred embodiment of the invention, planar elements are mounted on the rotor blade suction side in a zone extending from the blade root to half the rotor blade's length. In especially preferred manner, said zone shall extend from the blade root to one third the rotor blade's length.

In an especially preferred embodiment of the invention, at least one planar element is mounted in a zone which, as seen from the blade root, is situated beyond a transition range wherein the sectional contour of the blade root merges into a lift generating contour. An element mounted in such a zone is appropriate for instance to interrupt an already extant cross-flow coming from the blade root zone and in this manner to eliminate interferences from laminar airflows in this zone.

In another preferred embodiment mode, at least one planar element is mounted in a zone extending from the blade root to the near side of a transition range where the blade root contour merges into a lift-generating contour. Because of the special conditions relating to rotor blades, the substantial portion of the interfering cross-flow arises in this zone near the blade root because this rotor blade root, on account of its contour depth, as a rule is not an aerodynamically advantageous contour. Accordingly the configuration of an element of the invention in this zone especially effectively suppresses the formation of cross-flows -- contrary to the case of the above described elements which are configured in a manner that

they prevent propagation of an already extant cross-flow into the power-delivering rotor blade zone.

In a further advantageous embodiment of the invention, the planar element is air-permeable at least segment-wise, for instance being a mesh or perforated. A planar element of this design when appropriately dimensioned, may better reduce cross-flows than a continuous planar element. Also such a design reduces the planar element weight.

In a further embodiment mode of the invention, the planar element is made of a metal, for instance high-grade steel or aluminum, of plastic, of compound materials such as GRP (glass-fiber reinforced plastic) or CFP (carbon-fiber reinforced plastic), or of a combination of such materials. Such a design assures that the element shall both be weather-proof and withstand the operational mechanical loads. It is understood that other materials may be employed in equivalent manner provided they meet the conditions of weathering and mechanical strength.

The invention applies not only to rotor blades but also to planar elements that may be aligned in a sectionally contoured wind-driven power-plant rotor blade substantially in the direction of the airflow and at a spacing from the suction side, their height and length being selected in a way that they shall implement an effective reduction of a cross-flow running outward from the blade root. These elements may also be used to retrofit already erected wind-driven power-plants.

A preferred embodiment provides that the planar element be configured to be tightly adjoining the contour of the rotor section. However the said element also may be deformed in elastic or plastic manner to allow matching it to the contour of the rotor section at the first instance it is assembled to it.

The present invention is shown in illustrative and schematic manner in the drawings of a preferred embodiment.

Fig. 1 is the topview of the suction side of a wind-driven power-plant rotor blade,

Fig. 2a is a section along line A-A of Fig. 1, and

Fig. 2b is a further section along line A-A of Fig. 1 in another embodiment mode.

Fig. 1 shows a rotor blade 10 having a leading edge 11, a trailing edge 12, a blade root 13, a blade tip 14, a suction side 15 and a pressure side 16. The relative thickness of the rotor blade decreases towards the outside from the blade root 13 to the blade tip 14. The leading edge 11 points in the direction or rotation of the rotor blade. Planar elements 17 and 18 are mounted in the direction of airflow at the suction side 15 and suppress cross-flows on the suction side 15 and preclude premature airflow detachment. A transition range 19 is characterized in that the contour of the blade root 13, which in this instance is cylindrical, merges into a pear-shaped, lift-generating contour. An arrow denotes the cross-flow.

Fig. 2a shows a section of the rotor blade along line A-A of Fig. 1, said blade having a leading edge 21, a trailing edge 22, a suction side 25 and a pressure side 26. The planar element 27 is mounted on the suction side 25 and runs from the leading edge 21 to the trailing edge 22 and suppresses cross-flows on the suction side 25.

Fig. 2b shows a further section of the rotor blade along line A-A in Fig. 1 for another embodiment mode, said blade having a leading edge 21, a trailing edge 22, a suction side 25 and a pressure side 26. The planar element 28 is mounted on the suction side 25 and runs from the leading edge 21 to the trailing edge 22, and is fitted with rounded edges. The planar element 28 is fitted with perforations 29 which, when appropriately sized, contribute to effectively suppress cross-flows on the suction side 25.